TECHNICAL DOCUMENT 3203
February 2006

A Fiber-Optic Tether for the Hull Search UUV

System Documentation

J. G. Buescher

SSC San Diego

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ADMINISTRATIVE INFORMATION

The work described in this report was performed for the Naval Explosive Ordnance Disposal Technology Division (NAVEODTECHDIV) by the Ocean Technology Branch (Code 2744) of the Ocean Systems Division (Code 274) Space and Naval Warfare Systems Center San Diego.

Released by
R. Arrieta, Head
Ocean Technology Branch

Under authority of
J. Walton, Head
Ocean Systems Division

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DOCUMENT DESCRIPTION

This document is divided into the following six sections:

Section I describes the installation and operation of a fiber-optic (FO) tether system developed to augment unmanned underwater vehicles (UUVs) conducting ship hull inspection missions.

Section II defines the required specifications that will allow the integration and installation of a fiber-optic (FO) tether system on unmanned underwater vehicles (UUVs) with ship hull inspection capability.

Section III provides the parts list and vendors list.

Section IV details the sequence required to assemble the UUV telemetry subassembly from parts described in the Bill of Materials.

Section V captures outcomes and design decisions based on trade studies, engineering analysis, and fleet user inputs that affect the final configuration of the fiber-optic (FO) tether system for the hull search UUV.

Section VI (CD) provides assembly drawings.

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SECTION I

INSTALLATION GUIDE AND OPERATING MANUAL

SECTION I
CONTENTS

Figures

1. OVERVIEW

1.1 PURPOSE

Section I describes the installation and operation of a fiber-optic (FO) tether system developed to augment unmanned underwater vehicles (UUVs) conducting ship hull inspection missions. The tether provides a conduit for real-time transmission of high-bandwidth primary sensor data from the UUV to a mission operator in a remote location. The tether system supports two-way communication with the host UUV, enabling data transmission from the UUV to an operator display console and command and control (C2) communications from the operator back to the UUV. The tether system minimally impacts the autonomous performance of UUV hull search missions.

1.2 OPERATING CONCEPT

The FO tether system relies on two-way optical transmission of mission sensor and C2 data to achieve real-time connectivity between the hull search UUV and a mission operator. Data must be transmitted over an optical fiber conduit to meet expectations for a system that operates at the data rates required by the UUV high-bandwidth primary (i.e., acoustic imaging) sensors. The tether system converts IEEE 802.3 standard 100BaseTX Ethernet® messages into optical data for transmission over the tether and then re-converts the data to standard Ethernet® for interface with a display console. The tether system allows for two-way data rates comparable to 100 Mbps Ethernet® communication, but over a considerably greater range and in a smaller package than is possible with traditional twisted-pair cabling.

1.3 PRIMARY SYSTEM COMPONENTS

The FO tether system consists of three primary subassemblies. These three subassemblies, when installed and linked together, form a single data pathway between the hull search UUV and a mission operator display console. The following subsections briefly describe these subassemblies.

1.3.1 Tether and Spool

The tether and spool subassembly consists of 300 meters of neutrally buoyant FO cable stored on a manually operated reel. The reel provides Ethernet® connectivity to the mission operator display console, and also houses a subset of the optical-to-electrical converter hardware in an enclosed hub. The reel contains a mechanical slip-ring assembly that passes Ethernet® messages through the rotating hub and feeds power from a 12-VDC power supply to the enclosed optical-to-electrical converter. Besides the reel, the tether and spool subassembly includes a 1.5-meter FO patch cable that interfaces between the UUV and the wet end of the tether cable. Junction is achieved via an FC-style feed-through adaptor. Figure I-1 shows the tether and spool components.

Figure I-1. Tether, spool, FO patch cable, and 12-VDC power supply.

1.3.2 FO Penetration

The FO hull penetration subassembly effects the passage of optical signals through the boundary of pressure vessels or electronic housing dry spaces on the UUV. The hull penetration subassembly consists of a high-pressure, stainless-steel adaptor fitted with a high-pressure optical feed-through. The assembled penetrator allows optical data transmission without compromising UUV water-tight integrity. Figure I-2 shows the hull penetration subassembly.

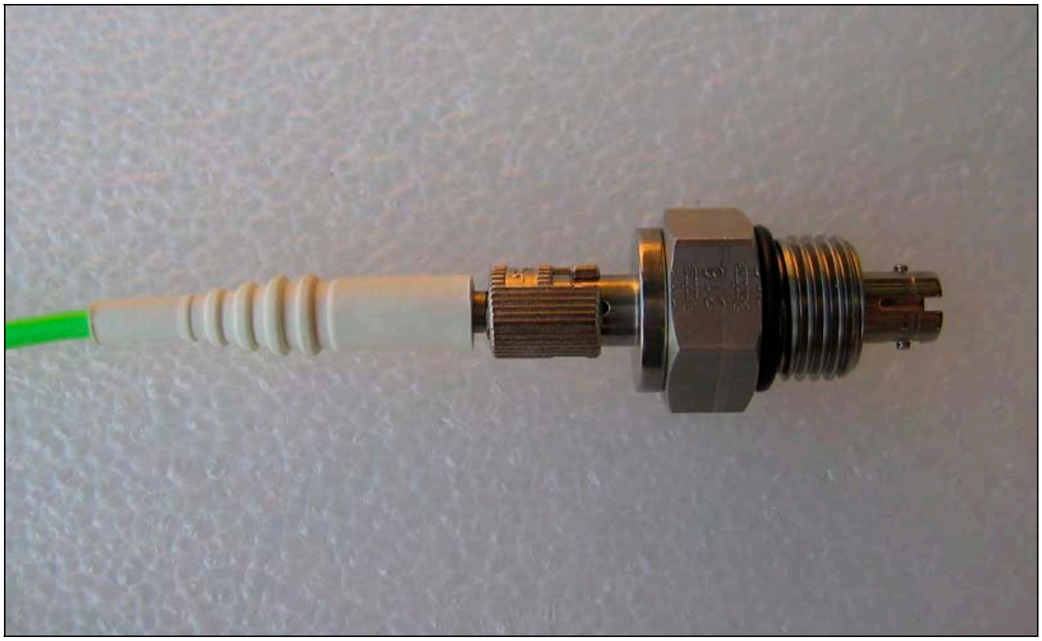

Figure I-2. FO hull penetration subassembly mated to FO patch cable.

1.3.3 UUV Telemetry Components

Optical-to-electrical converter hardware must be installed inside the UUV electronics housing to transmit optical UUV sensor data. To provide mounting and electrical power, the optical-to-electrical converter must be affixed to a custom PC/104 form-factor printed circuit board (PCB). In this configuration, the PC/104 bus provides the required 5-VDC power for the UUV telemetry components. The optical-to-electrical converter may be installed by assembling it onto an existing PC/104 card stack. See Figure I-3.

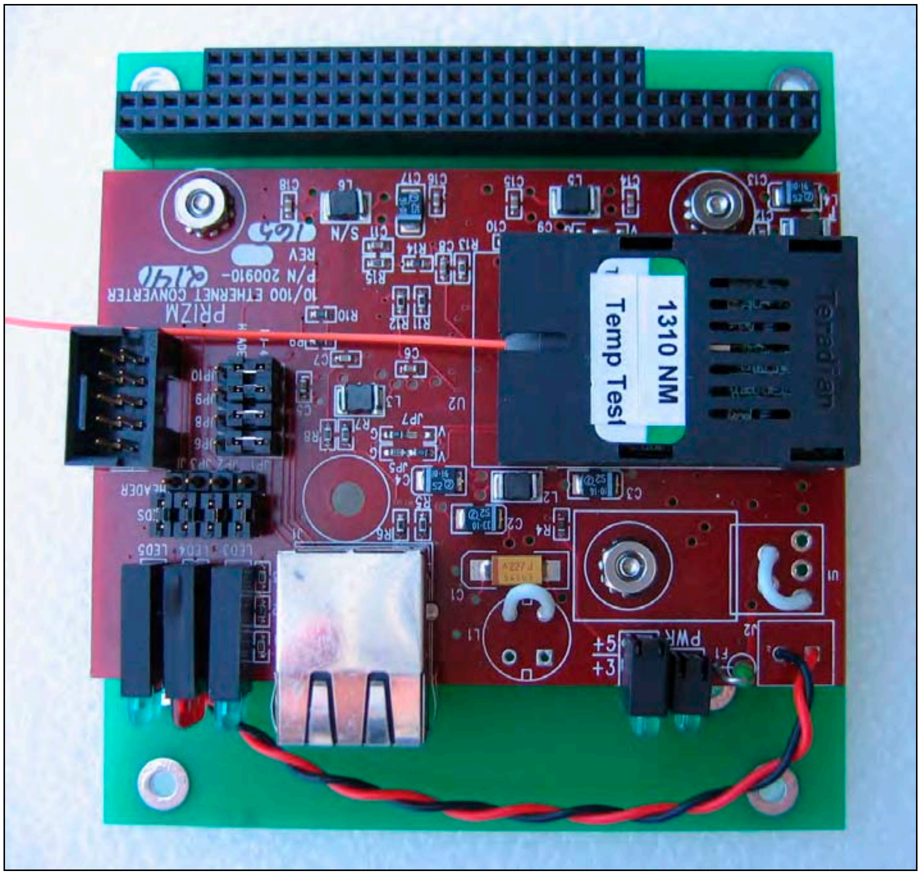

Figure I-3. Electro-optical converter and PC/104 card adapter.

2. SYSTEM INSTALLATION

2.1 UUV TELEMETRY COMPONENTS

To install the electro-optical conversion hardware, you must assemble the PC/104 adapter card, which mounts the telemetry components onto an existing PC/104 bus. You may use standoffs or spacers, as appropriate, to ensure proper clearance is maintained between the telemetry card and other devices in the stack. Ensure that 5-VDC power is available within the PC/104 bus onto which the card is assembled. Alternatively, use any 5-VDC power supply with an appropriate adapter. Figure I-4 shows the installation of the UUV telemetry components onto a typical PC/104 device stack.

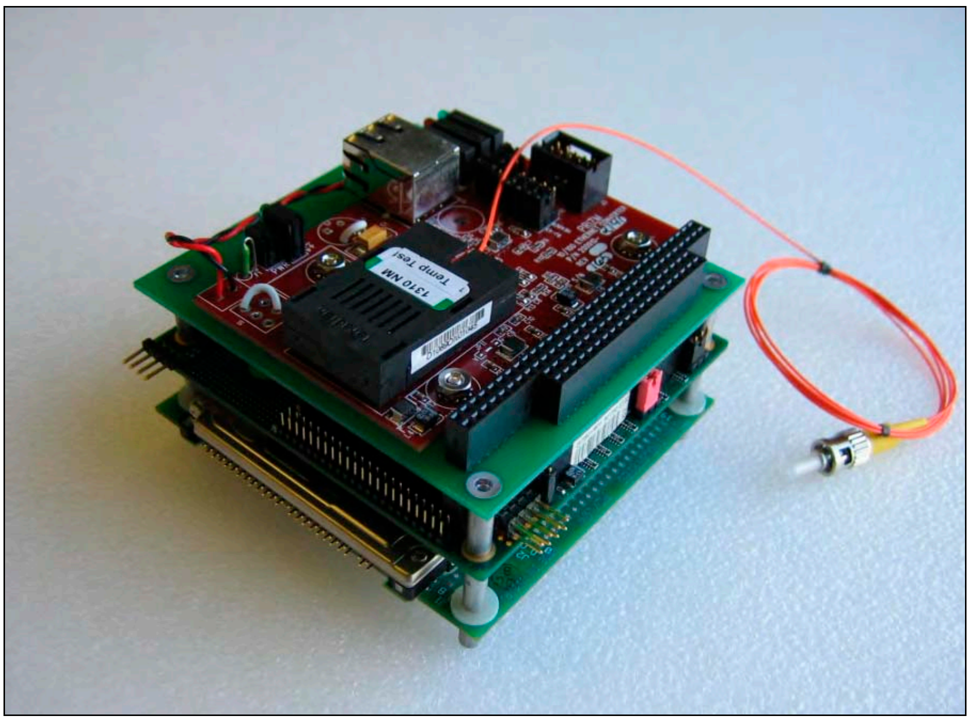

Figure I-4. UUV telemetry component mounting.

If power to the telemetry components is sourced from the PC/104 bus, the device will power on and off with the bus. No supplemental power switching is provided on the electro-optical conversion hardware or the PC/104 adapter card.

2.1.1 Ethernet® Signal Routing

A standard twisted-pair Ethernet® cable provides data connectivity between the electro-optical conversion device and the UUV. A board-edge RJ-45 connector on the telemetry card provides termination for an Ethernet® cable routed to the network or a processor onboard the UUV.

NOTE

If the electro-optical conversion card is to be routed to an Ethernet® hub onboard the UUV, a crossover adapter or crossover cable must be used. If the data are routed directly from a computer, processor, or auto-switching hub onboard the UUV into the telemetry card, no crossover is required. See Figure I-5.

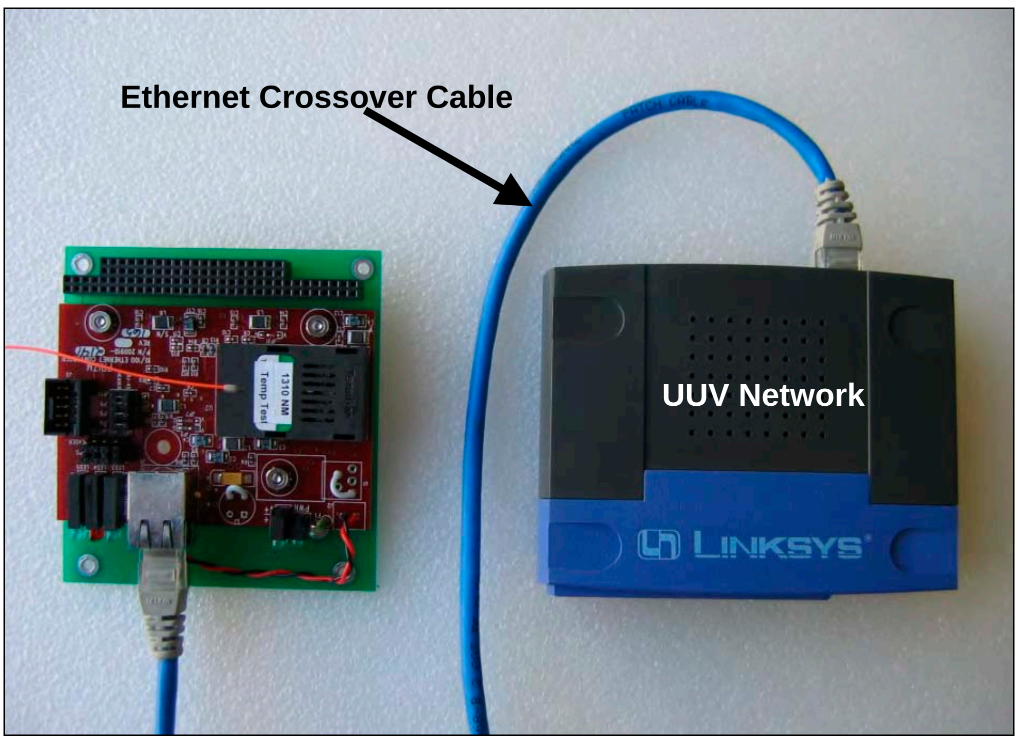

Figure I-5. Ethernet® signal routing to hub/switch from telemetry card.

2.2 FO HULL PENETRATION SUBASSEMBLY

Install the FO hull penetration subassembly in an appropriately machined through-hole where internal and external clearances are adequate to provide for routing of FO cables that must mate to the FO penetrator. You may use standard hand tools to install the hull penetration subassembly, but be careful not to damage the sealing surfaces or otherwise compromise subassembly integrity. Apply a good quality O-Ring lubricant before installation.

2.2.1 Optical Signal Routing

The internal (dry) and external (wet) faces of the hull penetration subassembly must mate with FO cables. Internally, this cable is affixed to the electro-optical conversion card. Externally, the hull penetration subassembly mates with a 1.5-m FO patch cable.

CAUTION

FO cables may fail if subjected to overly tight bend radii. When internally and externally routing FO cables, as much as possible, limit the number of bends in the cable. Bend radii should not be less than 2.5 cm, where possible, with an absolute limit of 1.25 cm. Figure I-6 shows an appropriate minimum bend radius at the internal interface with the hull penetration subassembly. Exceeding the minimum allowable bend radius will cause failure.

CAUTION

The FO signal cable affixed to the electro-optical conversion card is NOT load-bearing. Be careful not to expose the cable to tensile or compressive bend stresses of any kind. Consider this limitation when routing FO cable, as stress on the cable will cause failure.

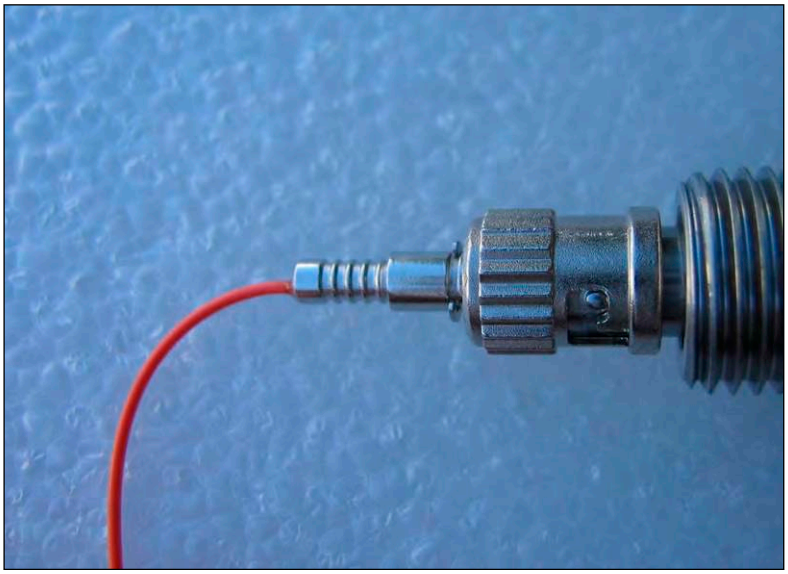

Figure I-6. FO cable routing (bend radius example).

2.3 TETHER TERMINATION

The tether must be optically and mechanically linked to the UUV before operation. Installing the tether system involves co-locating a mechanical tether termination hard point and the free (wet) end of the 1.5-m FO patch cable that optically links the tether cable to the UUV hull penetration fitting.

2.3.1 FO Patch Cable

Connect a 1.5-m FO patch cable to the UUV at the point of optical hull penetration. The patch cable has different fittings on each end and the ST style connector must be mated with the through-hull penetration fitting. Link the free or wet end of the patch cable, fitted with an FC style connector, via a coupler to the tether's wet end. Figure I-7 shows the components associated with the patch cable and its linkage to the primary tether.

CAUTION

The FO patch cable is NOT load-bearing. Be careful not to expose the cable to tensile or compressive bend stresses of any kind. Consider this limitation when routing FO cable, as stress on the cable will cause failure.

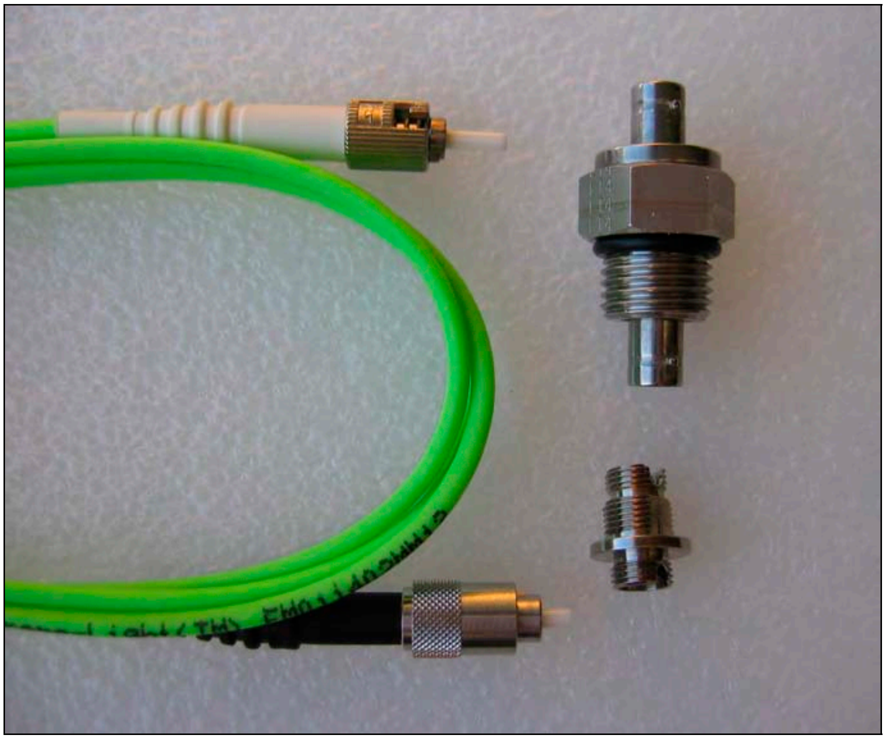

Figure I-7. Clockwise from top right: FO penetrator, FC-FC coupler, patch cable (FC fitting), patch cable (ST fitting).

2.3.2 Mechanical Termination

The tether cable (wet end) provides a mechanical linkage to allow attachment of the tether to the UUV. This mechanical linkage (Figure I-8) transmits load from the tether into the mechanical structure of the UUV without placing any stress on the optical junction. Attach this linkage to a suitable load-bearing hardpoint on the UUV.

CAUTION

The integrity of the mechanical termination linkage is critical to tether system operation. If improperly secured, the mechanical termination may fail and allow tether loads to be transmitted to the optical coupling and FO patch cable. Load on the optical coupling or FO patch cable will cause failure.

Figure I-8. Mechanical termination shackle.

2.3.3 Optical Coupling

Use the FC-FC optical coupler to form a junction between the FO patch cable and the tether's wet end. To assemble, insert the free (wet) end of the FO patch cable into the coupler and secure the locking collar. Then, insert the free (wet) end of the tether into the opposite side of the coupler and secure the locking collar. Figure I-9 shows the components required for the optical junction before assembly. Figure I-10 shows the completed junction.

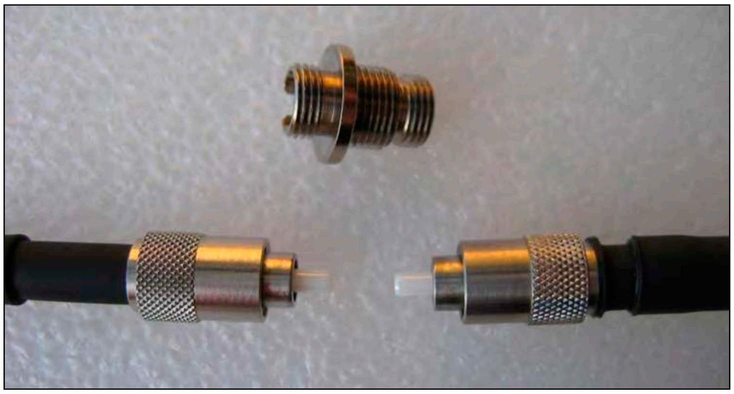

Figure I-9. Tether junction components (unassembled).

Figure I-10. Assembled tether junction.

2.3.4 Final Wet-End Termination Configuration

Figure I-11 displays a typical, complete termination on the tether wet end at the UUV interface. The mechanical termination and optical coupling are visible.

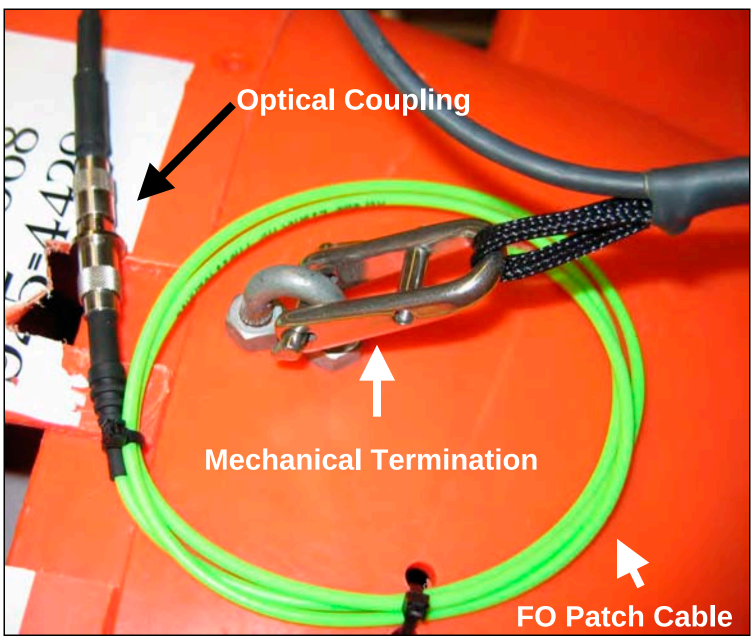

Figure I-11. Tether termination final installation.

2.3.5 Topside (Dry-End) Termination

To install the tether system, you must complete two connections on the tether topside or dry end before operation. These connections (Figure I-12) include a RJ-45 Ethernet® connection to a host computer or network and a 12-VDC power connection for the tether spool telemetry components.

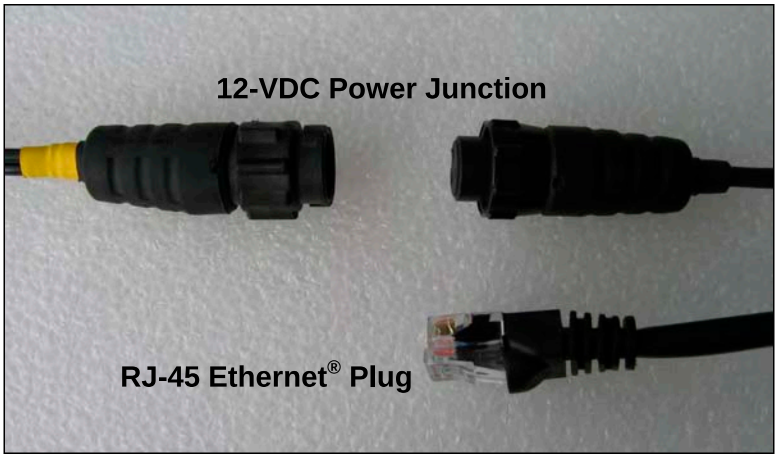

Figure I-12. Dry-end tether spool terminations.

Figure I-13 shows a standard termination of the topside tether connections. The RJ-45 Ethernet® plug is routed directly to a computer that serves as the operator's console. The 12-VDC power connector has been joined with the power supply. In this configuration, the spool would be powered on and ready to receive or transmit data over the tether.

NOTE

If the tether spool RJ-45 Ethernet® termination will be routed directly to a computer or auto-switching hub as part of a topside network, no crossover adapter is required. If the tether spool Ethernet® termination is routed into a standard hub or switch as part of a topside network, then an Ethernet® crossover adapter is required.

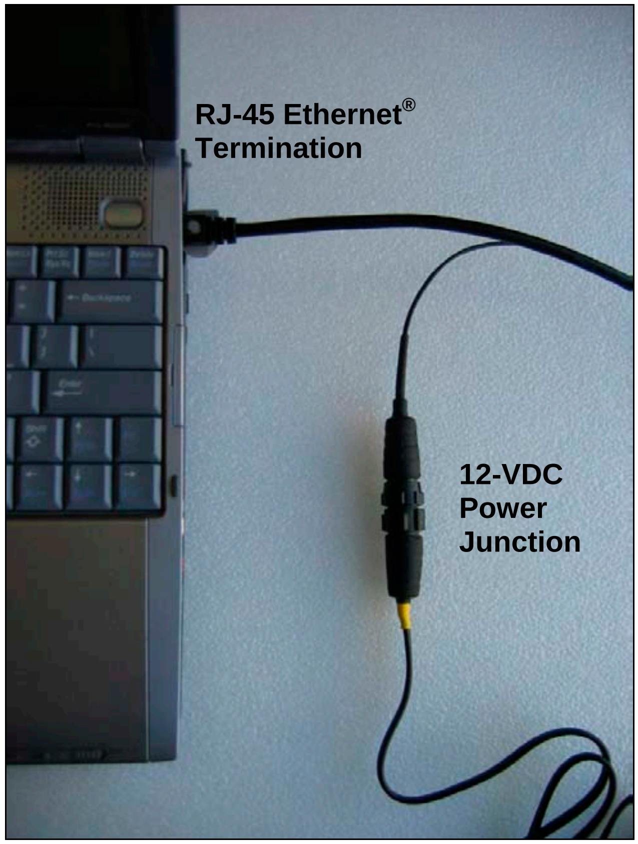

Figure I-13. Tether spool terminations (installed).

3. SYSTEM OPERATION

3.1 OPERATING LIMITATIONS

The FO tether system has several operational limitations that must be considered whenever the system is used.

3.1.1 Working Load Limit

The tether system is designed for repeated use and has an operational working load that balances strength with size and weight requirements.

CAUTION

The maximum working load for the FO cable is **25 kgs (55 pounds)**. Never subject the tether system to tensile loads greater than 25 kgs, or the optical components may become stressed and fail. NEVER use the tether to free a stuck or damaged UUV. NEVER use the tether to retrieve a UUV that you suspect may be stuck or damaged. Only use the tether to recover free-floating UUVs if load induced does not exceed **25 kgs (55 pounds)**.

3.1.2 Tether Length Limit

The FO provided with the tether spooling system is **300 meters (930 feet)** long. Avoid operations with the tether fully deployed to limit stress on the FO cable termination within the spool.

3.1.3 Buoyancy

The FO cable provided with the tether system is neutrally buoyant in seawater. Besides minimally impacting UUV mission performance, neutral buoyancy allows the tether to minimize contact with bottom or overhead obstructions during a hull search.

CAUTION

While minimizing unwanted bottom or overhead surface contact, neutral buoyancy alone does not ensure that the tether cable will never contact potentially fouling surfaces during a hull search mission. Continually monitor the deployed tether cable for signs of overstress or entanglement during use and recover the system if it becomes fouled.

3.2 SYSTEM POWER-UP

Power must be applied to the tether system at the UUV and topside spool ends before the system can be operated. To apply power at the UUV end, 5-VDC power must be energized and available via the PC/104 bus to which the telemetry card is mounted. Topside power is applied, as described in section I, subsection 2.3.5, via the 12-VDC adapter plug using a 12-VDC power supply. Alternatively, any 12-VDC power supply with an appropriate adapter may be used.

3.3 SPOOL OPERATION

The tether system spool is manually operated, relying on an operator to pay out and recover the cable. To operate the spool:

1. Remove the handle from its stowed position and affix it to the center hub of the spool. See Figures I-14 and I-15.

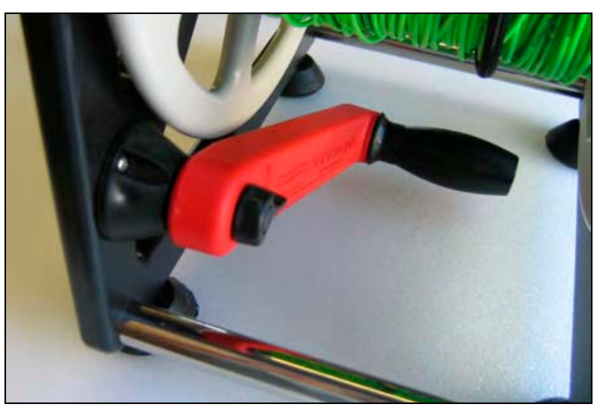

Figure I-14. Spool handle (stowed position).

Figure I-15. Spool handle (ready for use).

2. Release the spool locking mechanism (Figure I-16).

Figure I-16. Spool locking screw.

3. Manually turn the handle to pay cable out from the spool. DO NOT operate the spool by allowing the UUV to directly pull cable from the hub. Maintain slack between the UUV and the tether spool to minimize stress on the FO cable.

4. To recover the tether onto the spool, reverse the winding direction and guide the cable onto the spool as it is reeled in.

NOTE

Maintaining slight tension while recovering the tether will prevent fouling as the cable is wrapped on the spool. The tether should be guided back and forth onto the spool during retrieval to evenly distribute the tether cable across the spool drum.

5. After recovery, re-stow the spool handle and lock the spool locking screw before transit.

3.4 STORAGE

The tether spooling system is equipped with a case that may be used for long-term storage or transit to and from an operating area. Before storage of the tether system, and after any deployment, thoroughly rinse all wet components of the tether spooling system with fresh water, including the spool, the tether cable, all optical connectors, the UVV FO patch cable, and the exterior face of the optical through hull penetration on the UUV. The FO patch cable remains affixed to the UUV with the tether disconnected for storage at the FC style junction (figure I-10), near the mechanical termination. Protect all optical connectors with covers after they have been rinsed and before any transit or long-term storage.

SECTION II

INTERFACE SPECIFICATION AND REQUIREMENTS

SECTION II
CONTENTS

1. INTRODUCTION

1.1 PURPOSE

Section II defines the required specifications that will allow the integration and installation of a fiber-optic (FO) tether system on unmanned underwater vehicles (UUVs) with ship hull inspection capability. Installation of the tether system requires placing telemetry system components inside of the UUV main pressure vessel or electronics housing, fitting a sealed FO penetration to this housing, and relaying and receiving sensor and vehicle state data over a defined data protocol.

2. MECHANICAL INTERFACE

2.1 PRESSURE VESSEL PENETRATION

A single through-hull penetration is required for routing the FO signal. This penetration allows fitting specialized sealed feed-through hardware and external attachment of the tether. The penetration consists of a single-threaded and appropriately counter-bored hole, as per the SAE J1926 (also MS16142) specification. The required thread size is 9/16-18 UNF-2B. Anodizing or coating of machined surfaces is left to the UUV manufacturer's discretion, though tether system hardware and fittings are 316 series stainless steel.

2.2 INTERNAL ALLOWANCES

2.2.1 Hardware Mounting

Installation of telemetry system components requires a space and mounting allowance inside the electronics housing/pressure vessel. An allowance must be made for the installation of a single, standard PC/104-type electronics card. The area where the card will be mounted should allow 1.2 inches of vertical clearance and should not be located closer than 3.0 inches to the through-hull penetration point.

2.2.2 Clearances

The FO cable and connectors that must be routed between the penetration point and the installed telemetry components require a conduit clearance inside the electronics housing. This clearance includes a 0.5-inch-diameter cylindrical volume, coaxial with the pressure vessel penetration and extending 3.0 inches from the pressure vessel inside surface. Another clearance is needed to route a 0.375-inch-diameter connector from the penetration area to where the PC-104 telemetry card will be mounted. Routing this connector should allow for an affixed cable to avoid bend radii smaller than 1.0 inches.

2.3 EXTERNAL CLEARANCES

Ensure that clearances around the pressure vessel penetration allow hardware to be installed on the outside of the housing. Clearance space must be adequate enough to fit the hand tools required to install standard 11/16-inch hexhead hardware and provide a 2.5-inch perpendicular standoff between the outside face of the pressure vessel at the penetration point and any surrounding objects on the UUV. The installed tether will probably be routed up and aft, away from the UUV. Ensure that this area of the UUV is somewhat accessible to the pressure vessel penetration.

3. ELECTRICAL INTERFACES

3.1 SUPPLIED POWER

Telemetry system components installed inside the main pressure vessel require a connection to electrical power. The provided power supply has a regulated 5-VDC output that supplies 5 watts continuously. Connection to the power supply will be accomplished via assembly of the PC/104 telemetry card onto an available, standard PC/104 bus. The telemetry card shall obtain regulated 5-VDC power whenever the 5-VDC power supply to the PC/104 bus is energized and available.

3.2 DATA CONNECTION

Telemetry components interface to the UUV data source via a standard RJ-45 Ethernet® connector. The UUV manufacturer will provide a straight-through (non-crossover) female RJ-45 socket in the area of the telemetry component mounting space, or access to an existing RJ-45 socket and sufficient clearance to route a signal cable between the telemetry components and that connection.

4. DATA INTERFACE

4.1 TRANSMISSION PROTOCOL

All data transfer between the ship hull inspection UUV and the real-time display station via the tether link will be conducted using high-speed Ethernet®. System-transparent telemetry components will handle the conversion between this format and the FO protocol that will transmit information, but all data relay will be conducted via 100-Mbps Ethernet® communication. The system will operate on the IEEE 802.3, 100BaseTX Ethernet® standard.

4.2 TRANSMITTED DATA

As stated previously, *all* data will be transmitted via an Ethernet® protocol, including mission sensor and UUV state (i.e., navigational) data. To be correctly displayed to the operator, all data must be synchronized as described in the following subsections.

4.2.1 Sensor Information

All mission-critical sensor data must be referenced to the current UUV state and relayed via the Ethernet® link:

DIDSON/MIRIS Imaging Sonar. Individual sonar frames must be stamped with current UUV mission clock time and relayed over Ethernet® while continuing to log on the vehicle. An X-Y position stamp is desirable, if possible, but only a time-stamp is required.

Sidescan Sonar (if applicable). Sonar images must be stamped with UUV mission time and/or X-Y position, relayed via Ethernet® while continuing to log on the vehicle.

Camera (if applicable). Individual images must be stamped with UUV mission clock time and relayed over Ethernet® while continuing to log on the vehicle. Alternatively, digital video may be streamed in real time.

4.2.2 Vehicle State Information

Besides sensor information, the Ethernet® link shall relay information on the current position and state of the UUV. The following vehicle parameters will be transmitted; others may be relayed at the manufacturer's discretion:

1. Current UUV mission clock time
2. X-Y position of the UUV—earth or ship-referenced coordinates
3. Vehicle pitch angle
4. Vehicle roll angle
5. Vehicle heading (magnetic, true, or ship-referenced)
6. UUV depth
7. Standoff range to the ship hull (if available)

4.3 DATA RATES

To prevent sensor data holidays and maximize the relevance of relayed vehicle state information, an update rate of 2 Hz or greater is required of all mission sensor (sonar, camera) transmissions and 1 Hz or greater for all UUV state parameters.

4.3.1 Latency

Data transfer will probably introduce some latency that will prevent an operator from seeing information in real time. Transmission and interpretation processes should be designed to minimize these delays, however. A latency of less than 1 second is expected.

4.4 SOFTWARE REQUIREMENTS

The specific data packaging protocol is left to the UUV manufacturer's discretion to minimize the impact of the tether system on existing UUV software architecture. This specification section lays out requirements for what information must be transmitted, but does not specify how that information will be packaged for transmission. The UUV manufacturer will provide a software package to interpret the data that the UUV has transmitted via Ethernet®, and this interpreted data will be available to operators and processes off-board the UUV.

4.4.1 Data Interpreter

The UUV manufacturer will develop a software package to (1) interpret the data stream relayed by the UUV, and (2) write interpreted data to files. This package should be designed to run on Microsoft Windows®-based operating systems, receiving data over a 100-Mbps Ethernet® link connection. Vehicle state and sensor information should be written to independent files. The manufacturer will provide source and executable copies of any code.

SECTION III
BILL OF MATERIALS

SECTION III
CONTENTS

1. PARTS LIST

Item	Assembly	Level	Part Number	Description	Source	Qty	Unit	Make/ Buy
1	Tether & Spool	1	URS175-FO	Umbilical Reel, 175 M, Fiber-Optic	SeaBotix	1	EA	Buy
2	Tether & Spool	2	EC601	Slip Ring, 400 VDC, 24 *installed in umbilical reel	SeaBotix	1	EA	Buy
3	Tether & Spool	2	FM0114	Cable, Fiber-Optic, Multi-Mode 3-mm Diameter, 300 M *loaded onto umbilical reel	SeaBotix	1	EA	Buy
4	Tether & Spool	2	200910-2141	Ethernet Board, TEL Series, OEM, 12 VDC, 1310 nm *installed in umbilical reel	SeaBotix	1	EA	Buy
5	Tether & Spool	1	DTS120200UC-P5P-KH	12VDC Power Supply, 100–240V, 50/60 Hz, 2A	SeaBotix	1	EA	Buy
6	Tether & Spool	1	CBA008	Cable, Fiber-Optic, Multi-Mode 3-mm Diameter, 1.5 M *terminated FC-ST	SeaBotix	1	EA	Buy
7	Tether & Spool	2	944-125-6003	FC Adapter, D-Hole, Feed-Through, Zirconia Ceramic Alignment Sleeve	Amphenol Fiber-Optic Products	1	EA	Buy
8	Tether & Spool	1	URC175	Transit Case for Umbilical Reel	SeaBotix	1	EA	Buy
9	Fiber-Optic Penetration	1	0213452	Connector Adapter, per SSC San Diego Drawing No. 0213452, CAGE Code 55910	N/A	1	EA	Make
10	Fiber-Optic Penetration	2	6P50N-SS	Extreme-Pressure 316 SS Threaded Pipe-Fitting Hexhead Plug, O-Ring, 9/16"-18 Straight Threaded	Parker O-Ring Division	1	EA	Buy
11	Fiber-Optic Penetration	2	500-SST-S1-B01-000	ST DRY® High-Pressure Permanent Bulkhead Feed-through, Single Mode (9/125)	Greene Tweed Aerospace Division	1	EA	Buy
12	UUV Telemetry	1	200910-2141	Ethernet® Board, TEL Series, OEM, 5 VDC, 1550 nm	Prizm™ ACE	1	EA	Buy

1. PARTS LIST (CONTINUED)

Item	Assembly	Level	Part Number	Description	Source	Qty	Unit	Make/ Buy
13	UUV Telemetry	1	TEL5VUUV002	PC-104 -5VDC Power Adapter, Printed Circuit Board	N/A	1	EA	Make
14	UUV Telemetry	2	1185C-104G	PC-104 Stackthrough 40 & 64 Position Connector	Comm Con Connectors	1	EA	Buy
15	UUV Telemetry	2	70553-0001	Connector Header, 2 Position, 0.100, Right-Angle, Gold	Molex®	1	EA	Buy
16	UUV Telemetry	2	50-57-9402	Connector Housing, 2 Position, 0.100 w/Latch	Molex®	1	EA	Buy
17	UUV Telemetry	3	16-02-1125	Connector Terminal, Female, 22-24 AWG, Gold	Molex®	2	EA	Buy
18	UUV Telemetry	3	83004	24 AWG Teflon Hookup Wire, AWM Style 1213, Red	Belden	20	Cm	Buy
19	UUV Telemetry	3	83004	24 AWG Teflon Hookup Wire, AWM Style 1213, Black	Belden	20	Cm	Buy
20	UUV Telemetry	2	92949A108	18-8 SS Button-Head Socket Cap Screw 4-40 Thread, 3/8" Length	McMaster-Carr®	4	EA	Buy
21	UUV Telemetry	2	92510A420	Aluminum Unthreaded Round Spacer 1/4" OD, 1/8" Length, #4 Screw Size	McMaster-Carr®	4	EA	Buy
22	UUV Telemetry	2	96278A005	18-8 SS Machine Screw Nut With Tooth Washer 4-40 Screw Size, 1/4" Width, 3/32" Height	McMaster-Carr®	4	EA	Buy
6S	Spares	1	CBA008	Cable, Fiber-Optic, Multi-Mode 3-mm Diameter, 1.5 M *terminated FC-ST	SeaBotix	1	EA	Buy
7S	Spares	2	944-125-6003	FC Adapter, D-Hole, Feed-Through, Zirconia Ceramic Alignment Sleeve	Amphenol Fiber- Optic Products	1	EA	Buy
9S	Spares	1	0213452	Connector Adapter, per SSC San Diego Drawing No. 0213452, CAGE Code 55910	N/A	1	EA	Make
10S	Spares	2	6P50N-SS	Extreme-Pressure 316 SS Threaded Pipe-Fitting Hexhead Plug, O-ring, 9/16"-18 Straight Threaded	Parker O-Ring Division	1	EA	Buy
11S	Spares	2	500-SST-S1-B01-000	ST DRY® High-Pressure Permanent Bulkhead Feed-through, Single Mode (9/125)	Greene Tweed Aerospace Division	1	EA	Buy

2. VENDOR LIST

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www.seabotix.com

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www.mcmaster.com

SECTION IV

UUV TELEMETRY CARD ASSEMBLY SEQUENCE

SECTION IV
CONTENTS

Figures

1. PURPOSE

Optical-to-electrical conversion hardware is mounted to a custom PC/104 form-factor printed circuit board (PCB) to facilitate delivery of electrical power to the telemetry components and to mount the components within the UUV (unmanned underwater vehicle) electronics housing. Section IV details the sequence required to assemble the UUV telemetry subassembly from parts described in the Bill of Materials.

2. ASSEMBLY SEQUENCE

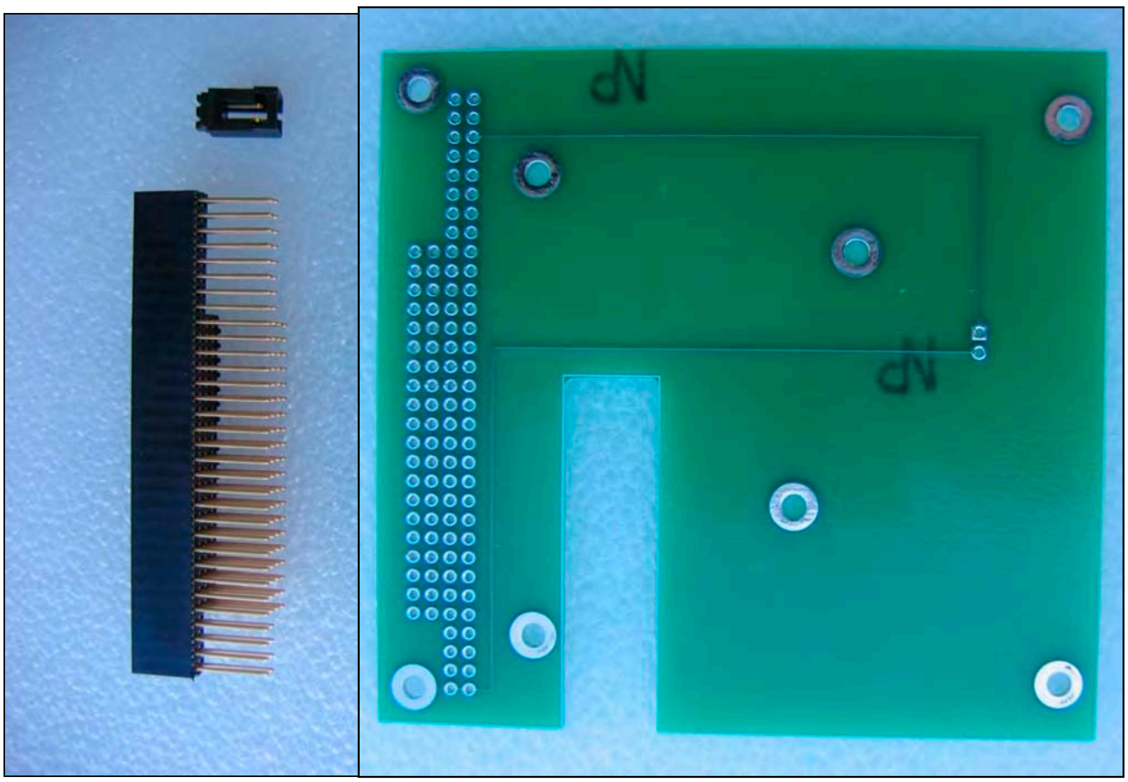


Figure IV-1. Custom PCB adapter card and connectors before assembly.

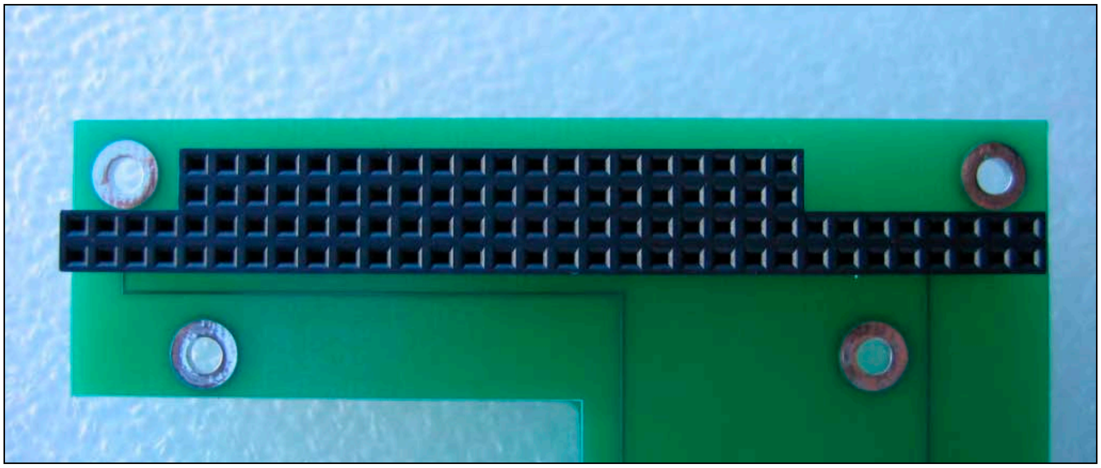


Figure IV-2. PC/104 connector assembled on PCB.

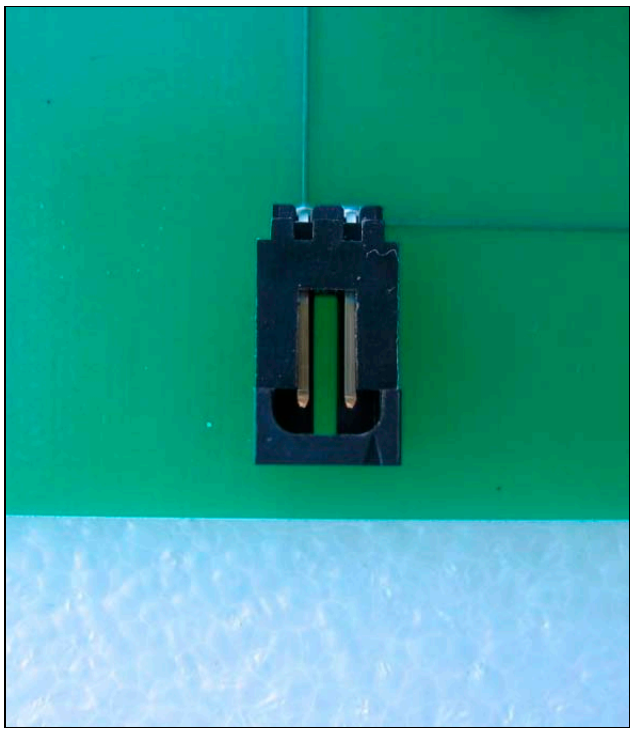


Figure IV-3. 5-VDC power header installed on PCB.

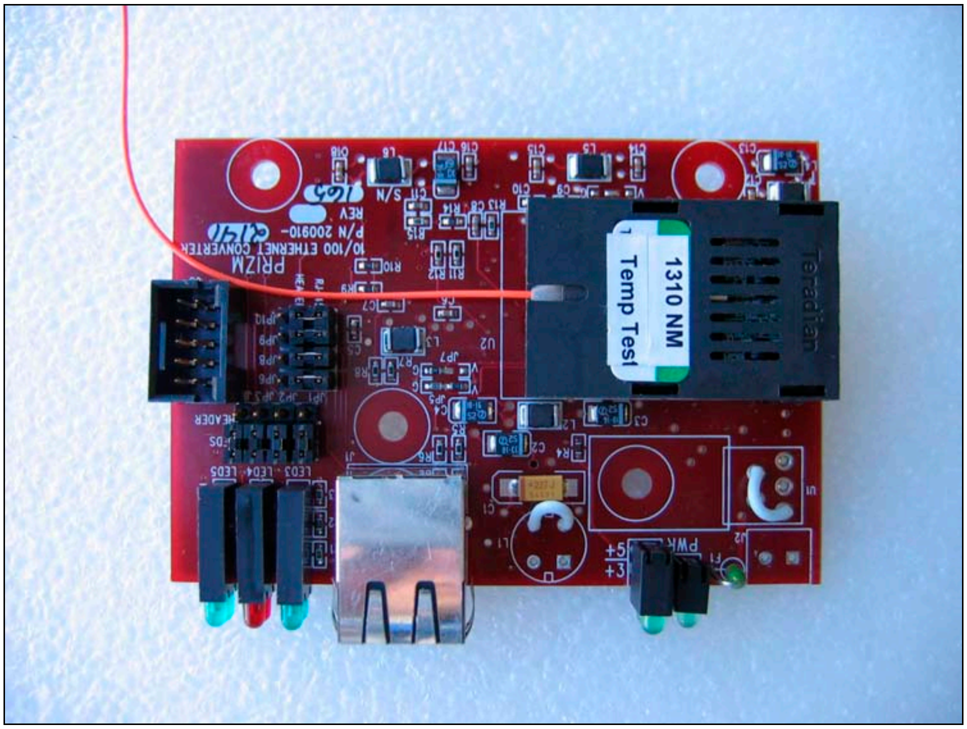


Figure IV-4. Prizm™ FO converter module before assembly.

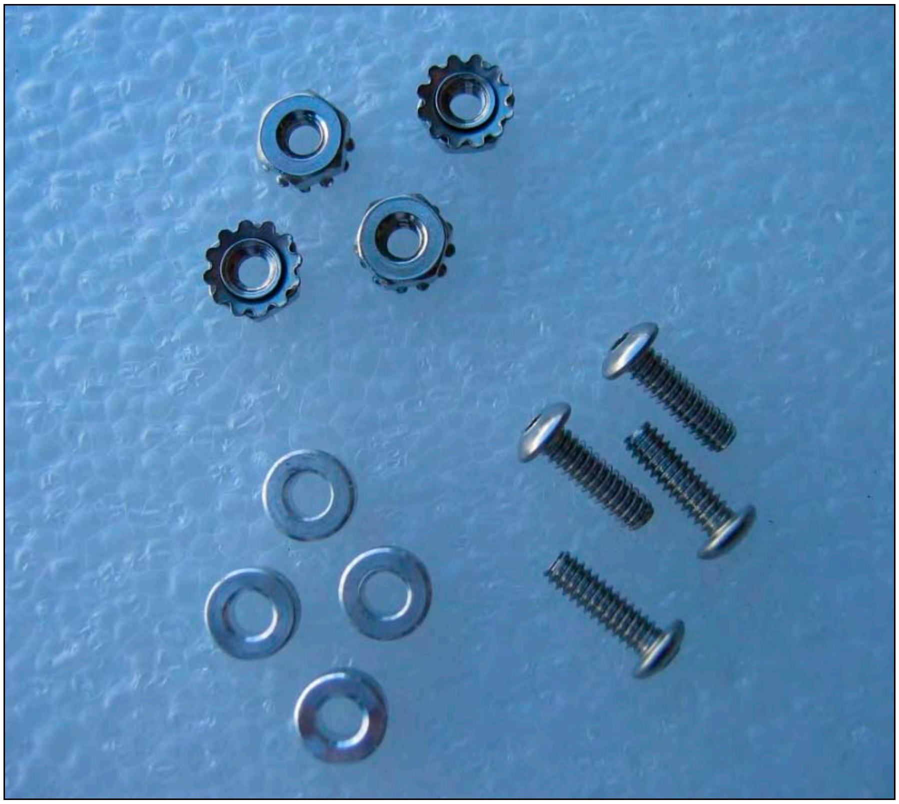


Figure IV-5. Screws, spacers, and lock nuts used to assemble FO module onto PCB card.

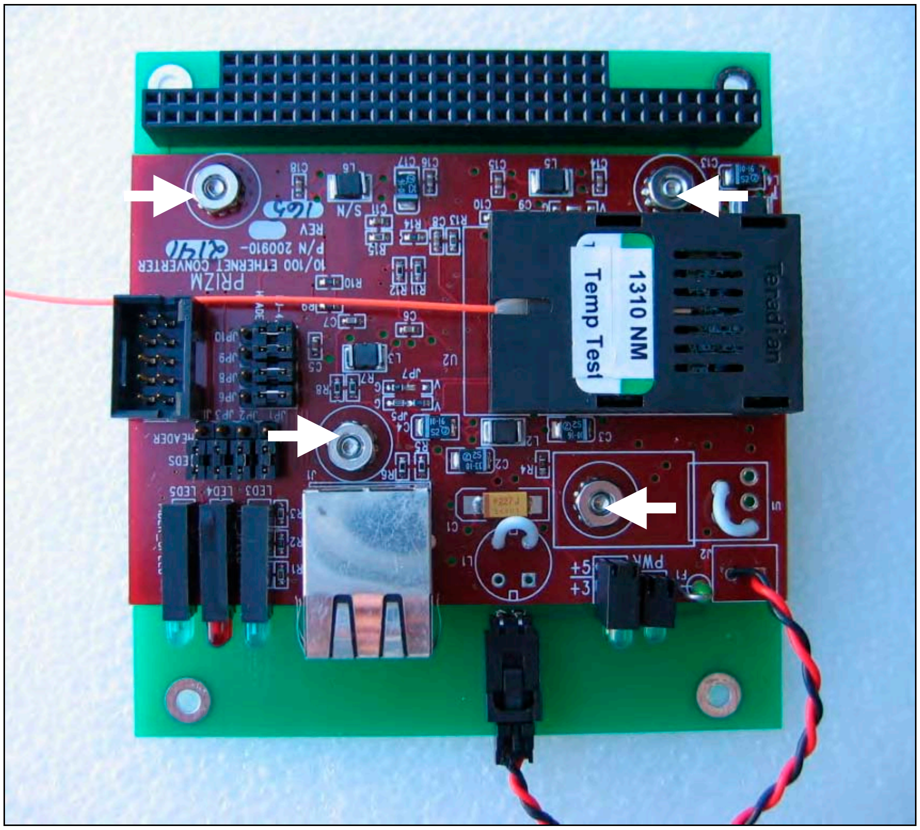


Figure IV-6. PC/104 card after installation of FO module. Note mounting screw locations.

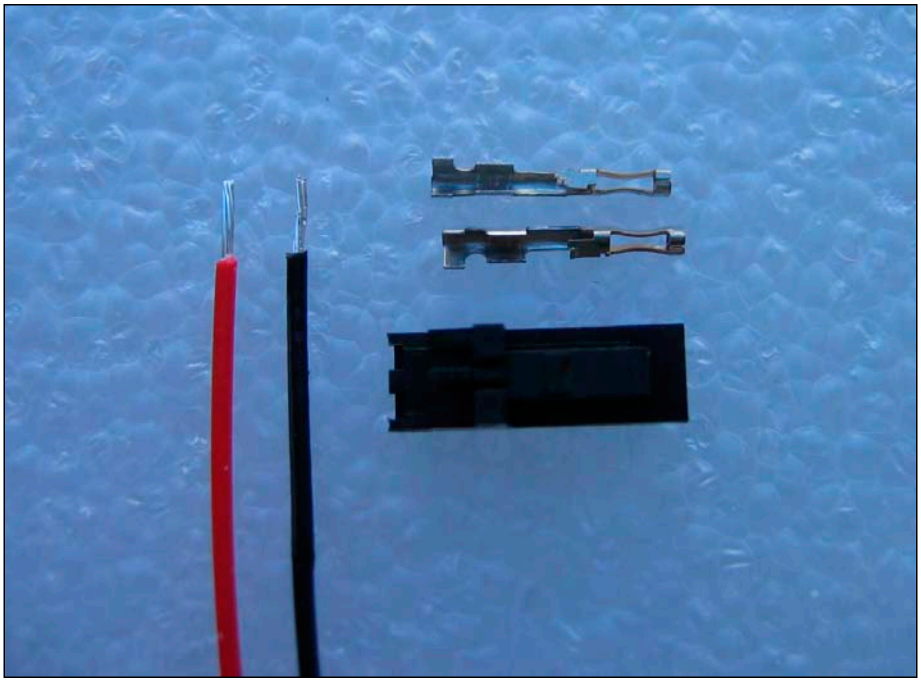


Figure IV-7. Power connector components before assembly.

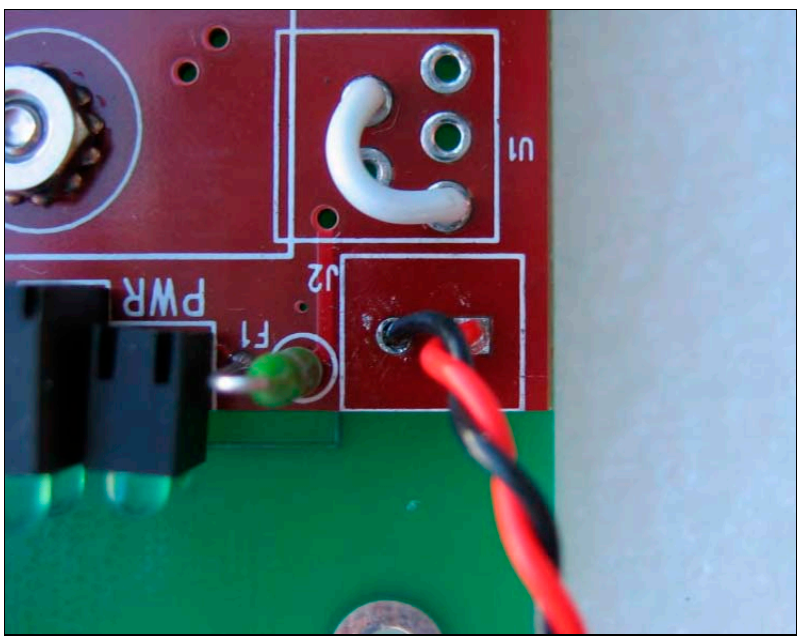


Figure IV-8. Assembled power connector leads soldered to FO module power pads. Note Pin 1 (+5 VDC) location (red wire).

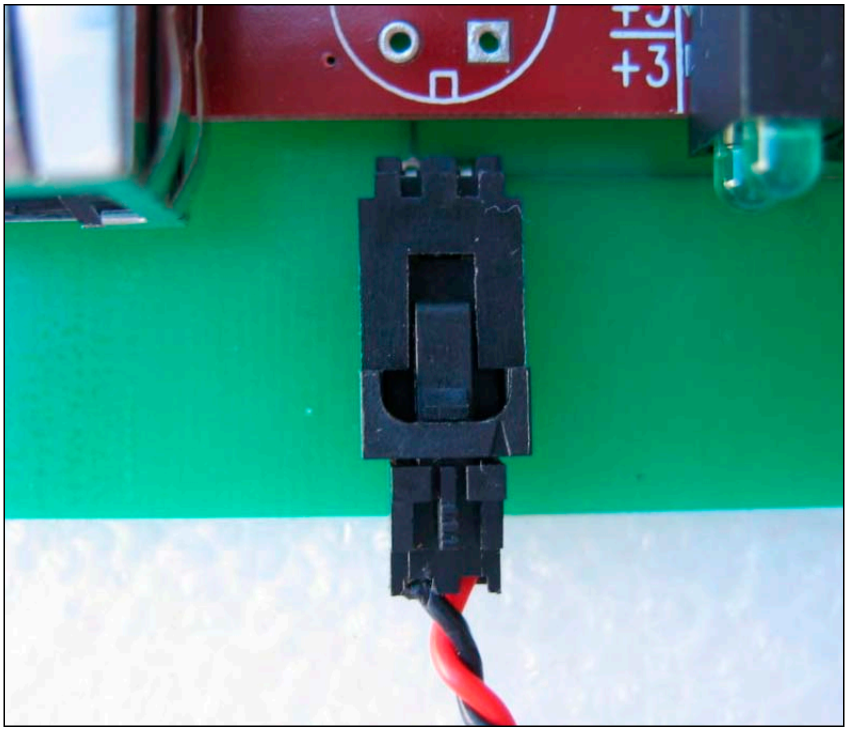


Figure IV-9. 5-VDC power connector mated to header on PC/104 card.

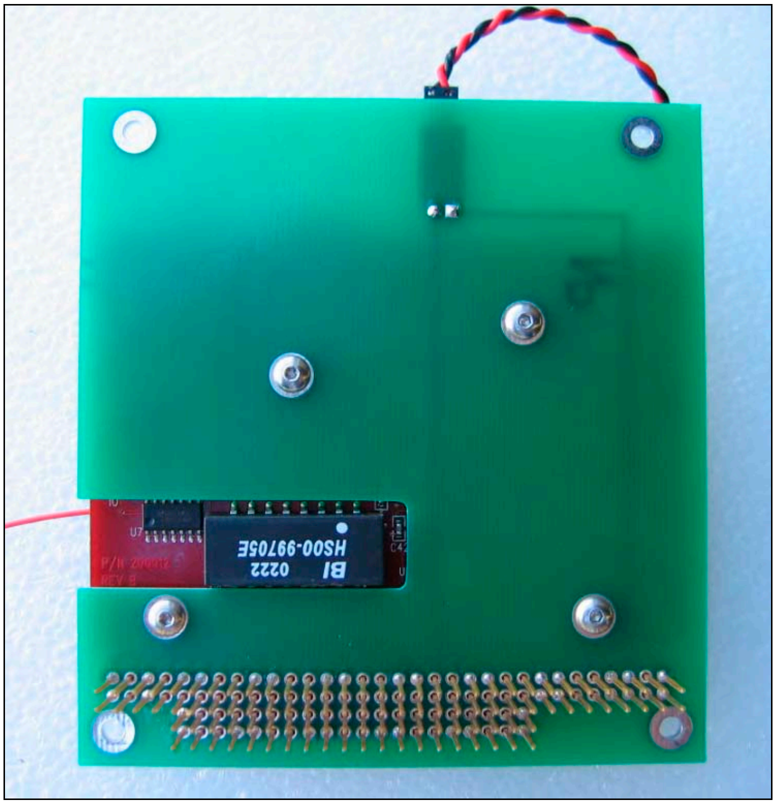


Figure IV-10. Completed assembly (bottom view).

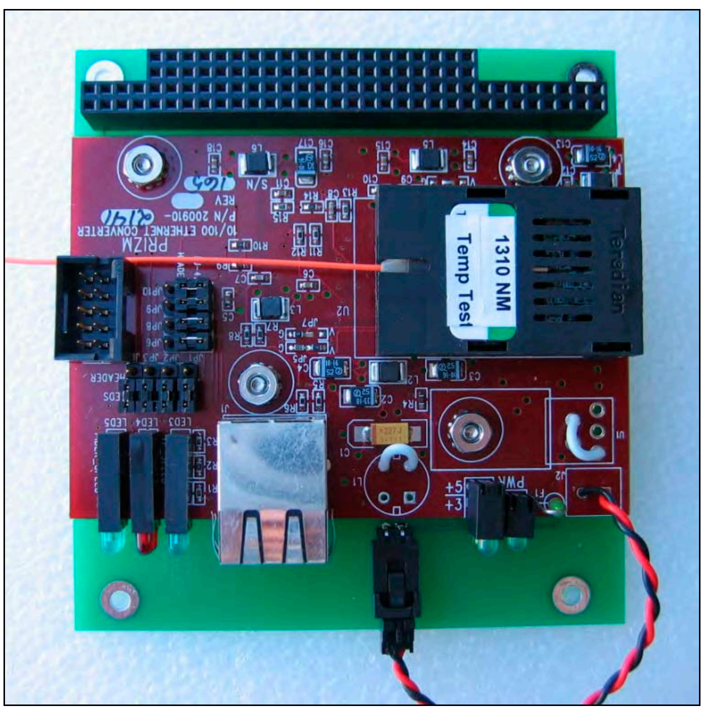


Figure IV-11. Completed assembly (top view).

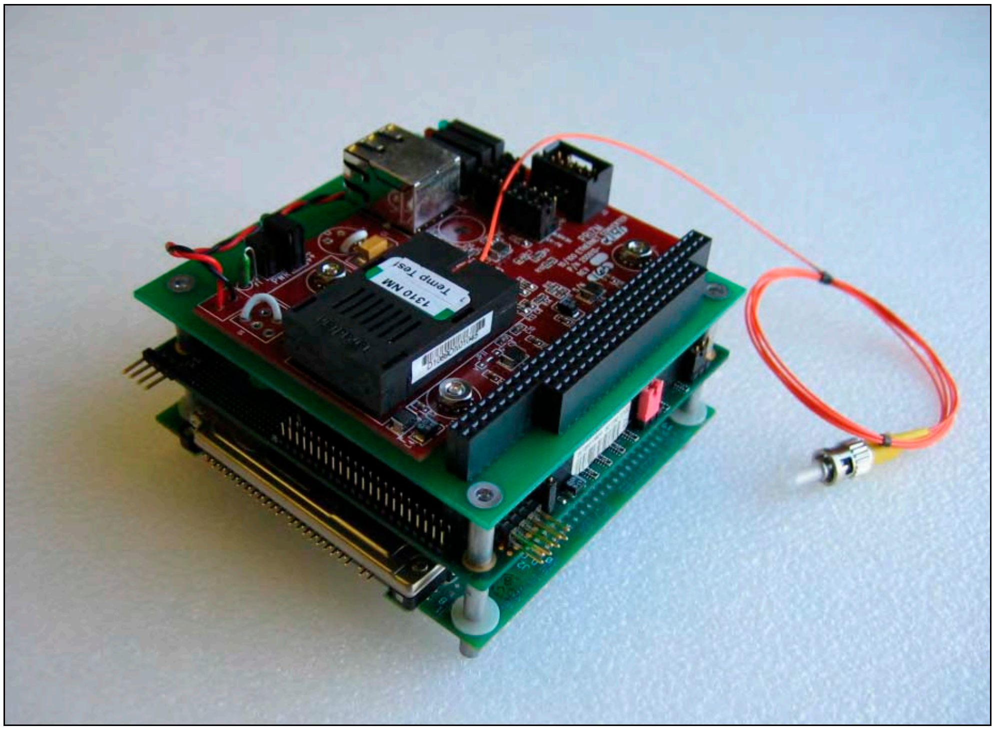


Figure IV-12. Completed telemetry card installed on typical PC/104 card stack.

SECTION V

SYSTEM EVOLUTION AND CONFIGURATION DESCRIPTION

SECTION V
CONTENTS

1. PURPOSE

This section captures outcomes and design decisions based on trade studies, engineering analysis, and fleet user inputs that affect the final configuration of the fiber-optic (FO) tether system for the hull search UUV. This section shall be updated to reflect design changes and system modifications as the tether system is fielded and user feedback is solicited, providing a record of such changes as appropriate.

2. TETHER COMMUNICATION CHARACTERISTICS

Two main types of tethers exist for use in underwater vehicles: copper and fiber-optic. Copper cables are cheap and rugged, but allow only limited bandwidth. FO cables are weaker (more prone to fracture) and are more expensive, but allow for much greater bandwidth. Appropriately shielded, an FO tether could be as strong as a regular cable.

The tether will deliver mission sensor information from the vehicle to the user in real time. When the design team began tether management selection, the main sensors on the vehicles under consideration were the DIDSON forward-looking sonar and an underwater camera. The DIDSON produced high-quality acoustic images at up to 24 frames per second, but the design team determined that a regular copper cable would be insufficient for the potentially high data rate necessary for displaying mission sensor data over the required ranges (200+ meters). They chose an FO tether for use in the tether management system. The team selected a Seabotix, Inc. tether management system that included an FO tether for evaluation.

3. TETHER MANAGEMENT SYSTEM

The fiber tether development team used three main constraints when choosing a tether management system: per-use cost, reliability, and usability. Two types of fibers were considered and evaluated in several payout scenarios: (1) a rugged, reusable tether deployed from the surface or an underwater depressor weight, and (2) a small disposable tether deployed from the vehicle, the surface, or both.

The team debated three potential payout scenarios:

1. A strong tether that pulls the vehicle and is spooled out on the surface by a person. This system would be the cheapest and easiest to implement. However, the system would be susceptible to fouling on the ship or other underwater obstacles.

2. A strong tether with a spool similar to scenario one but spooled out underwater by a diver or automatically. This system would be more expensive, especially if incorporating an automatic payout and retrieval system. However, this configuration was considered less susceptible to fouling.

3. A small, one-time-use FO tether spooled out from the vehicle. This configuration would guarantee that the tether would not get snagged. However, the tether would have a very expensive per-use cost and the tether might not be retrievable after each use.

The third scenario was rejected quickly, along with any other one-time-use tether as the per use cost would be too great. Potential tethers used for this purpose have a cost on the order of $1000 per kilometer. A vehicle could traverse several kilometers when inspecting a large ship.

The fiber tether development team opened discussions with Explosive Ordnance Disposal Mobile Unit Seven (EOD-MU7) for their input. EOD-MU7 had used tethered vehicles (remotely operated vehicles [ROVs]) for ship hull inspection and had many lessons learned in tether management. EOD-MU7 recommended the tether system developed by Seabotix, Inc. that was used by the company’s ROVs. The Space and Naval Warfare Systems Center San Diego (SSC San Diego) team also had experience with the Seabotix tether management system. No other tether management system matched the availability and reliability track record of the Seabotix system.

4. URS175FO SPOOL DEVELOPMENT

The URS175FO spool, as originally delivered by Seabotix, required several modifications to remedy production issues and incorrect wiring. The following subsections document correspondence from SSC San Diego engineers with the vendor (Seabotix) in resolving those issues.

4.1 URS175FO-001 HUB WIRING CORRECTION 20 SEPTEMBER 2005

The current wiring on the spool system hub, from the RJ-45 connector through the slip-ring and into the installed TEL Series Ethernet Board, is incorrect. Modifications are required to remedy the signal paths in order for the spool to function properly. The corrected wiring connectivity is described below, along with the present incorrect wiring.

As Presently Wired (INCORRECT):

J3 (2x5) Connector		*RJ-45 Connector*
Pin 1(orange)	→	Pin 6(green)
Pin 2(red)	→	Pin 3(green/white)
Pin 3(green)	→	Pin 2(orange)
Pin 4(yellow)	→	Pin 7(brown/white)

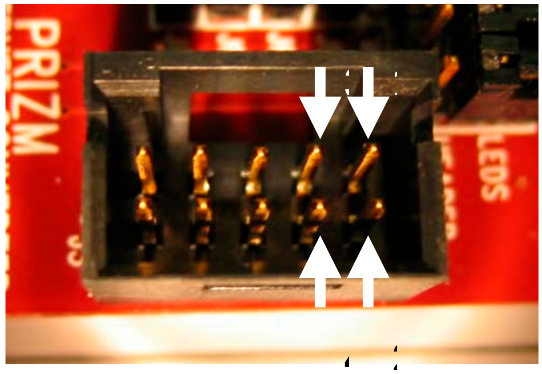
Required Wiring (CORRECT):

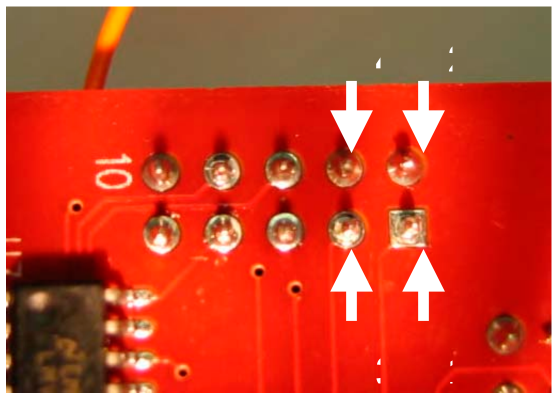
J3 (2x5) Connector		*RJ-45 Connector*
Pin 1	→	Pin 1(orange/white)
Pin 2	→	Pin 2(orange)
Pin 3	→	Pin 3(green/white)
Pin 4	→	Pin 6(green)

4.2 URS175FO-001 HUB WIRING CORRECTION 23 SEPTEMBER 2005

The problem with the wiring was that the connector block that routed wires from the slip-ring into Header J3 (2x5 10-Pin) on the Prizm™ board had been improperly pinned (juxtaposed). The signal wire which should have routed to Pin 1 was in fact routed to Pin 10, and the signal that should have routed to Pin 2 was installed in the Pin 9 position, etc.

Below are two pictures of the Prizm™ TEL Card (P/N 200910) J3 Header, with the Pins labeled for clarity:





Again, as previously related, and as listed in the Prizm™ TEL converter manual, the CORRECT wiring is as follows:

Required Wiring :

J3 (2x5) Connector		*RJ-45 Connector*
Pin 1	→	Pin 1(orange/white)
Pin 2	→	Pin 2(orange)
Pin 3	→	Pin 3(green/white)
Pin 4	→	Pin 6(green)

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14. ABSTRACT

This document describes the installation and operation of a fiber-optic (FO) tether system developed to augment unmanned underwater vehicles (UUVs) conducting ship hull inspection missions, defines the required specifications that will allow the integration and installation of a FO tether system on UUVs with ship hull inspection capability, provides the parts list and vendors list for this system, details the sequence required to assemble the UUV telemetry subassembly from parts described in the parts list, captures outcomes and design decisions based on trade studies, engineering analysis, and fleet user inputs that affect the final configuration of the FO tether system for the hull search UUV, and provides assembly drawings for the system.

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